PARAMOUNT FERTILIZERS.

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Think science, talk practice. This is the aphorism for an instructor to ever bear in mind, as only correct thought can be expected to lead towards correct application, and science is the method of the arrangement of facts. Hence, in the pithy sentence of our introduction, we would express our sense of the duty of the lecturer towards his audience, his fundamental duty of stating facts in such orderly arrangement that the teachings shall have reference to applied art, and shall presumably be correct in statement and application. I would also further express my views of an additional duty that devolves upon a lecturer at such a meeting as this; and this duty consists in stimulating thought in the hearers, by taking the audience into partnership as it were with the speaker, by expressing in words the thought and the science which leads to the practical talk which is expected by the audience. If, therefore, in a lecture which deals with the greatest of economical sciences, that of farming, the thought in the lecture takes precedence of practice, the audience must approve, as they consider that in practical success thought always takes this precedence, and that the interest in the practical conclusion necessarily must increase in accordance with the fullness and correctness of the thought which precedes as well as explains. I propose, hence, to think before you and talk to you.

My subject is not only one of practical import, but is also an intricate one, and hence, in order to keep within the bounds of the time assigned me, it will be necessary to use illustrative facts alone, and appeal to the consensus of tried experience for the securing of wider generalization. If, by implication, I also appeal now and then to the individual experience that shall confirm what science explains and scientific thinking here formulates, I may be pardoned in thus calling my audience into the exercise of that partnership in thought to which I have already alluded.

From Aug. 18 to Sept. 23, 1883, at intervals of a week, five corn plants at each collection, or thirty in all, were analyzed at the New York Agricultural Experiment Station.* The average result of these analyses offers a fair illustration of the composition of the corn plant at the period of its best condition. The figures of the analyses are: —

Water,	79.04	
Ash,	.81 of which	phos. acid, .08 potash, .28
Albuminoid,	2.06 = nitrogen, .33	
Crude fiber,	4.65	
Nitrogen — free extract,	12.92	
Ether extract,	.51	

These constituents can be roughly separated into two classes: 1st, Those removed from the soil; 2d, Those removed from the soil and atmosphere. The water and ash, or 79.85 per cent of the total, comes from the soil, as also some little of the remaining constituents. The carbon comes from the atmosphere directly, and is built up into the various carbohydrates. It is not necessary to our purpose to calculate the exact relations, but only to call attention to the fact that in the plant, *water*, which is taken from the soil, constitutes fully 79 per cent of the weight of the living plant, while the ash and nitrogen combined do not exceed 1.14 per cent, and the phosphoric acid but .08 per cent, and the potash but .28 per cent.

Transpiration in plants is the escape of aqueous vapor that has accumulated in the intercellular spaces, through the stomata of the leaves, and it varies in amount with the character of the plant, the moisture of the atmosphere, the intensity of the light, or the temperature, wind, etc.; or, in other words, upon those changeable conditions that occur between plants and their relations towards environment, which are principally, in turn, the relations which find ex-

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* Report of N.Y. Ag. Ex. Sta. for 1883, pp. 153-155; 163.

pression in the concrete term climate. It is hence difficult to determine the *average* amount of this transpiration; but we can readily determine the amount of water thus given off by individual plants under given conditions, and can readily reach the conclusion of its enormous proportions and importance. Prof. Boussingault* found that in the case of the Jerusalem artichoke in a pot, each square metre of foliage exhaled hourly 65 grammes in the sunshine, 8 grammes in the shade, and 3 grammes at night. Wiesner† found that from 100 square centimetres of green maize leaf there were transpired in one hour: in darkness, 97 milligrammes; in diffused daylight, 114 milligrammes; and in sunlight, 785 milligrammes. In some experiments carried forward at Rothamstead,‡ Sir J. B. Lawes reports that, from March 19 to September 7, the quantity of water given off by various plants, under different circumstances of manurial application, were as follows: —

Each trial.	Grains.
Wheat, 3 plants,	55,996 — 113,527
Barley, 3 plants,	85,124 — 120,025
Bean, 1 plant (Vicia faba),	112,231 — 117,869
Pea, 1 plant,	96,405 — 109,082
Clover, 1 plant,	13,671 — 55,093

At a later date, in 1871, he reports § as a summary of results attained, that "in the growing and ripening of either graminaceous or leguminous corn crops, probably on the average from 250 to 300 parts of water are given off for one part of total dry substance, fixed or assimilated;" or, as summarized later by a writer,‖ that for every ton of really dry substance grown, a depth of three inches of rain would be evaporated through the vegetation; and this, let me remind, is for England, with its moist climate and sunshine of little intensity. Calculating from this data, we would have, in a corn crop of 50 bushels, a total yield of about 4 to 5 tons of plant, containing from 1,600 to 2,100 pounds of dry matter, which, multiplied by 300, — for the maize plant is a great

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* Popular Science Monthly, Jan., 1879, p. 365.

† Ann. de Sc. Nat. (6), 14, 1887. Goodale Phys. Bot., 278.

‡ Hort. Trans., 1850, p. 45.

§ Jour. R. A. S., 1871, p. 93.

‖ W. H. Wheeler. Jour. R. A. S., 1878, p. 15.

evaporator of water, and the American climate is an intensely evaporative one, — represents a loss, through exhalation, of at least 240 to 315 tons of soil water per acre; or, as an inch of rainfall is equivalent to about 100 tons per acre, to an equivalent of from two to three inches of rain.

Returning now to our illustrative analysis, we find that of water and the other constituents usually reckoned as paramount in importance, viz., nitrogen, phosphoric acid and potash, our estimated crop of 50 bushels of corn, in its growing, removes from the soil, approximately: —

Water,	6,323 —	7904 lbs.
Nitrogen,	26 —	33 lbs.
Phosphoric acid,	6 —	8 lbs.
Potassa,	22 —	28 lbs.

Let us now review the extent of evaporation from the soil. In England, where, on account of the moist climate and rather equable temperature, the yearly losses through evaporation from the soil, either directly or indirectly, are comparatively uniform, they are usually estimated in considering the water supply of cities at from nine to sixteen inches of rainfall; in this country, with its drier and warmer climate, they are very variable, but are found on the average to equal about one-half of the rainfall; or say from fifteen to thirty inches of water.* The authority quoted, continues: "As illustrating the difference in capacity to absorb moisture of the atmosphere of the two countries (England and America), it may be stated, that the mean yearly evaporation from water surfaces was determined by six years of experiment at Whitehaven, England, to be 30.03 inches; while experiments lasting for one year at Ogdensburg, N.Y., showed it to be there 49.37 inches, and at Syracuse, N.Y., 50.2 inches. Observations taken at Salem and Cambridge, Mass., determine it at about 56 inches." In experiments with water surfaces at Plaistow,† England, the rate of evaporation was found to be 91.2 per cent of the rainfall, and trials at Dijon, in France, gave the rate as 96.6 per cent of the rainfall. At Orono, Me.,‡ evaporation from a water

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* Report of the Cochituate Water Board for 1873, p. 11.

† Jour. of Agr. 2d ser., xii., p. 400.

‡ Fernald. Agr. of Me., 1869-75.

surface during the period from May 20 to October 17, was 18.54 inches; and at Milwaukee, Wis., from March 15 to November 14, as a five years' average, 32.58 inches.

From a soil surface, we have it stated by Dr. Dalton * as the result of observations during the years 1796 and 1798, in England, that the mean evaporation was 25.158 inches, and for the six months, April to September, inclusive, 16.788 inches, the largest amount being 4.095 inches in July, and 3.386 inches in August. Later, Mr. Dickinsou † determined the average evaporation from a lysimeter for equal years, 1836 to 1843, as 15.320 inches, or 57.6 per cent of the rainfall. Other foreign determinations ‡ are those at Rothamstead, the average of five years, 63.2 to 71.4 per cent of a 28-inch rainfall; those at Geneva, Switzerland, 61 per cent of a 26-inch rainfall; those at Orange, France, 80 per cent of a 28-inch rainfall. American trials have given the following figures as calculated for the Waushakum Farm lysimeter at South Framingham, Mass., from 1876 to 1878, inclusive: —

	Rainfall.	Evaporation.
1876, . . .	43.88 in.	89.2 per cent.
1877, . . .	43.22 in.	73.6 per cent.
1878, . . .	54.36 in.	83.0 per cent.

or during the growing months, June, July, August and September: —

	Rainfall.	Evaporation.
1876, . . .	13.98 in.	97.5 per cent.
1877, . . .	9.40 in.	98.8 per cent.
1878, . . .	15.08 in.	99.9 per cent.

The figures derived from the New York Agricultural Experiment Station lysimeters, § from Aug. 1, 1882, to Nov. 1, 1887, inclusive, show an average evaporation of 73.4 per cent of the 23.724 inches of rainfall, being 85.4 per cent from sod, 70.7 per cent from bare soil, and 63.9 per cent from cultivated soil. The average for June, July, August and September, growing months, was 84.04 per cent of the 11.84 inch rainfall.

* Mem. of the Lit. and Phil. Soc. of Manchester, v. pt. ii.

† Jour. R. A. S. 1856, p. 127.

‡ Scientific Farmer, Feb. 1878, p. 17; Feb. 1879, p. 15.

§ Report of N. Y. Ag. Ex. Sta. for 1887, p. 397.

From a few districts we have careful estimates of the evaporation which takes place from large areas under natural conditions, and such have been gathered together by Dr. S. M. Babcock,* as follows: —

WATERSHEDS.	Years of Record.	Rainfall, Inches.	Evaporation, Inches.	Evaporation, Per cent of Rainfall.
Lake Cochituate, Mass., .	29	49.11	27.03	55.04
Sudbury River, Mass., .	6	46.10	24.17	52.43
Mystic River, Mass., .	5	42.78	23.13	54.06
Croton River, N.Y., . .	13	46.64	20.29	43.50
Mean, ...	–	46.16	26.35	51.23

As Croton River flows mainly through a sparsely settled region, and the other watersheds are in a populous and cultivated region, the figures for evaporation may be considered as approximately similar for the several localities.

We may now review our scientific data, by stating the following propositions as approximately correct: —

1. The amount of water contained in one corn crop is 70 times that of the nitrogen and ash constituent, and amounts to about 79 per cent of the weight of the plant.

2. The amount of water transpired from one corn crop during its growth is equivalent, at the least, to from 2 to 3 inches of rainfall.

3. The amount of water lost from the soil through evaporation during the growing months is over 98 per cent of the rainfall at South Framingham, Mass., and over 84 per cent at Geneva, N. Y., as measured by the lysimeters; or allowing for surface drainage, which occurs on natural areas, is probably at least 100 per cent of the rainfall or more. For the year, from natural areas, this loss is over 50 per cent of the rainfall; as measured by the lysimeter in Massachusetts, about 82 per cent of the rainfall; at Geneva, N. Y., 73 per cent.

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* Report N. Y. Ag. Ex. Sta. for 1887, p. 389, *et seq.*

Passing now to practical data, which may wisely take the form of propositions, as being verifiable by common experience, we may note as of importance for our purpose: —

1. The variation of crop as between different years is far greater than occurs the same year between different fields differently fertilized, under conditions of fairly good farming, thus proving the importance to farming of the conditions generally included under the concrete terms, season and climate.

2. The variation in crop between different fields of similar treatment is manifestly dependent on the soil relations to moisture, as may be readily verified by careful and intelligent observation and trial.

3. The conditions of climate (or season) which principally affect the crop, as recognized yearly by farmers, is the greater or less amount of rainfall, as the farmer construes his observations; or, as the more observant man construes it, the distribution of the rainfall, and the extent of evaporation. (August, on the average, is the month of greatest rainfall, and usually greatest drought.)

4. In regions where there is less available water for the growing crop (not necessarily a small rainfall) there is found to exist the practice of more distant planting, and fewer plants to the hill, than where the conditions of water supply are more favorable. This may be illustrated practically by the 5 by 5 feet intervals and single plants to the hill practiced in the seaboard South, and the 3½ by 3½ feet intervals and four plants to the hill of New England practice, or experimentally by the following record of trial at the New York Agricultural Experiment Station,* 1882 being a dry and 1883 a moister season: —

CORN. METHOD OF PLANTING.	YIELD PER ACRE.	
	1882.	1883.
Hills 2 by 2 feet, 4 kernels to a hill, . . .	7 bush.	28½ bush.
Hills 3½ by 3½ feet, 4 kernels to a hill, . .	49¾ "	49½ "

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* Report N. Y. Ag. Ex. Sta., for 1883, p. 137.

The corollary from this table, which experience confirms, I shall digress to state as a fact, viz : That in Massachusetts, with a rainfall of 45 inches a year, it is as easy to grow one hundred bushels of shelled corn per acre, as at Geneva, N. Y., with its 25 inches of annual rainfall, it is to grow seventy-five bushels, and this irrespective of the fertility of the soil.

5. Weeds are great evaporators of water. By trial I have found that a weed crop may be absolutely incompatible with a corn crop, the corn crop showing in its curled leaf, stunted growth and yellow color indications of suffering from drought, and not bearing any merchantable ears. In the experience of farmers such evidence becomes graded, and can serve as a less intensified illustration than the one quoted.

The summary of this practical data is that crops, under circumstances of intelligent farming, are more dependent upon the water supply for their maximum increase than upon any other single agency.

My audience will now discover that I class water as one of the paramount fertilizers, but before continuing I desire to caution that within the limits of an address I cannot present the whole evidence, or treat the matter as I would, and hence use but one crop, the maize crop, as illustrative. I propose to only go far enough here to excite interest and thought, and after making my propositions probable, proceed to the practical point of how to grow a crop under the best auspices for success ; how to utilize this fertilizer which nature pours down and lifts up to each surface ; how to retrieve from abundance to secure against the calamity of want. I would again remind that not only is water a component of plants, but it is a conveyor for plants, bringing to them matter in solution, which goes towards building up structure, and acts as a conveyor within the plant, so that we may say that it is the life, in the sense that we say the blood is the life. I would also remind that deserts are usually such, not from lack of elements of plant food, but through aridity, as is evidenced by the results of reclamation through the agency of the irrigation ditch or the artesian well in Algeria, our western plains and elsewhere. And, while digressing, I may as well remind you that all arable soil contains the fertility requisite for multitudes of crops, and that under artificial conditions under which water relations can be controlled, crops can be raised indefinitely, as in China, Japan, India, Palestine, etc. Where irrigation is practiced the average crop seems to have held its own for hundreds, even, perhaps, thousands of years of continuous culture under the trained art of native husbandmen.

It is now necessary to consider the movement of soil water, and in doing this I shall draw largely upon the data accumulated at the New York Agricultural Experiment Station, under my own supervision, and under immediate charge of Mr. E. S. Goff, the horticulturist.

As a general rule, the water content of the soil increases as we go downward, and the undersoil thus furnishes a grand reservoir of moisture which is available for the return of water to the surface through the action of capillarity, when not too remote, and when conditions are favorable. The great loss of water to the soil is through drainage and evaporation. The first is usually of little consequence for our present review, except in its absence, for cultivated soils should be well drained, either naturally or artificially. The second is of great import, as the loss through evaporation is greatly in excess of the loss through percolation (if percolation can be considered a loss to the crop), and this our figures heretofore given are sufficient to prove. We may state, however, that the water which flows from drains during the growing season in our climate is rarely the water of immediate rainfall, but that of displacement, or more usually that of the water-table, to which drains may be considered as standing in the relation of an overflow. At Geneva, N. Y., the water-table in 1887, as measured by the depth of well water from the curb (the well, happily for our purpose, being situated on a swell of land which carried the soil surface below the depth of the well bottom at a distance of a few hundred feet in each direction), was 4 feet 2¼ inches below the surface on May 1, 6 feet 10 inches on June 1, 9 feet 2 inches on July 1, 10 feet 5¾ inches on Aug. 1, 11 feet 3 inches on Sept. 1, 13 feet 4½ inches on Oct. 1, and 15 feet 4½ inches on Nov. 1, soon after which date the distance gradually decreased. This water-table was *unaffected by the rainfall* during the growing season. Capillarity, as measured by soil in tubes (a far less satisfactory way than in natural soil, but far more certain for experimental purposes), was traced vertically 44 inches, and probably would have extended farther had the experiment been designed for this purpose, but slight breaks in the column are apt to retard or terminate capillary progress. In natural soil, or bluffs along a shore, the base in contact with water, I have noted the effect of capillarity in raising water apparently a dozen feet or more. Horizontally the action of capillarity carries water more rapidly and farther than it does vertically. In nature capillarity brings an immense body of water to the surface, to be removed as aqueous vapor by evaporation, and in this manner, during some months, an amount of water exceeding the rainfall of the month thus disappears into the atmosphere. Evaporation is practically a surface phenomenon, and may be checked in great degree by any device that shall prevent capillary water from reaching the surface. The lysimeters at Geneva, N. Y., had for surfaces, sod, bare soil, and frequently stirred soil. The first showed evaporation and transpiration combined, the second allowed the capillary water to reach the surface unchecked, the third had the capillary pores displaced by stirring of the surface, and thus retarded the flow of capillary moisture to the surface. For illustration we will quote the figures obtained. For the month of August, 1887, with a rainfall of 3.03 inches, in lysimeter No. 1, the sod, there was no drainage, all the water of rainfall, and more, being evaporated and exhaled, a good illustration of the drying influence of crops; in lysimeter No. 2, bare soil, the drainage was .695, leaving 2.337 inches of the rainfall as evaporated; in lysimeter No. 3, cultivated soil, the drainage was 1.055 inches, leaving of the rainfall 1.977 inches to be calculated as evaporated. Thus 2.337 inches, minus 1.977 inches, leaves .360 inches in favor of the cultivated area. This .360 inches means 9,775 gallons of water per acre conserved. In 1886, under different conditions of rainfall and climate, the difference between the two lysimeters was even greater, indeed enormous, and offers convincing proof of the efficacy of cultivation in conserving moisture at a time when moisture is most needed by the crops — it was 4.11 inches, or 111,607 gallons per acre; the rainfall being 2.86 inches. In 1885 the difference in amount evaporated between the hardened and the stirred soil was .208 inches, or 5,648 gallons per acre, with a rainfall of 5.02 inches. In 1884 the rainfall was 1.44 inches, the saving by the process of cultivation not indicated by our apparatus, as there was no percolation from either lysimeter, but in September, with its 3.17 inches of rainfall, the effect of cultivation was seen in the greater recovery of the stirred lysimeter from its extreme dryness and the saving of 6,707 gallons per acre. In 1883 the saving by cultivation for the month of August, with 3.47 inches of rain, was 10,671 gallons, and in 1882, with 2.37 inches of rainfall, was 11,948 gallons of water per acre. I offer these figures in quite full detail, as the importance of the saving is so great that I would impress the fact of the saving, and its possible enormous proportions, upon the minds of all, and having offered the explanations and the facts, I would enforce the practical conclusion that cultivation, or the stirring of the upper layers of the soil, breaks capillary connections with the evaporating surface, and thus retards the loss of water and conserves the water for crops, which, as I have already shown, require a really enormous supply, and whose yield is dependent very largely on this supply. Cultivation is a mulch, and it conserves water, as our above figures show, and this is important to remember, much more in a drought than at other times.

Capillary action is exerted inversely in proportion to the diameter of the tubes or pores, and is stopped at once by a crack or space which interrupts the continuity of the capillary tubes or pores. Hence, in soil, the rate and distance of the action is regulated by the size of the pores in the soil and their abundance, and is checked by any loss of continuity. When water stagnates in the soil the earth particles are liable to come into close contact, the soil may become, if trampled, puddled, as we say, and hence the water of the soil may move rapidly towards the surface and disappear as aqueous vapor. This explains, in part, why undrained clay soil in cultivated fields suffers so severely from wetness in spring and drought in summer; this offers valid reason for the usefulness of drainage; this explains, in part, the apparent paradox that drained soil in summer often contains more water in a drought than does like soil that is undrained, a fact which at one, at least, of our experiment stations was considered so unorthodox that it became the subject of experimental trial and *was demonstrated.* In ploughing, the turned soil does not rest in close contact with the under soil until consolidation is effected by rains, etc., and the disturbed section gives of its own moisture to the atmosphere and regains but little from the stored water below. In the spring, when water is abundant and evaporation comparatively slight, no ill effects are perceived. In the summer, however, with shallow ploughing, it is often difficult to secure germination of grass seed, or the continued life of the weak seedling, as the water from the disturbed soil is quickly evaporated and little additional supply can reach it by capillarity from the water stored below. The turning under of raw manure by the plough tends to form a strata disconnected from the surface compressed by the plough sole and. the inverted surface. This is injurious to capillary action for a long period; and thus, during the dry season of the year, the ploughing under of raw manure is followed by a dryness of the workable soil which injures it for the reception of crops. This may be illustrated by the difficulty realized in securing growth of strawberry plants that are transplanted upon what is called a thoroughly prepared plot in August, or upon land to which rather long manure has been applied; and the success which follows such transplanting when, by means of a roller, or by trampling, the soil thus enriched or fined is closely compressed, and thus brought into close capillary union with the lower undisturbed soil.

The theoretical conditions under which, with proper climate, the best plant growth takes place, for cultivated plants at least, is the conjunction of the best physical condition of the soil as regards relationship to water, and the permeability to plant roots with sufficient fertility. Thus, in greenhouse culture, the florist cannot use soil that is loose in the pots; but he carefully compresses it so as to bring the particles into closer contact, and carefully avoids wetness during the process so as not to puddle his soil, and thus render it impermeable to roots and too evaporative of water; he uses a mixture with sand, and crocks below, in order to obtain proper drainage and permeability to water. He seeks to obtain those conditions whereby his soil shall never become unduly wet with stagnant water, never unduly dry, always permeable. In the larger culture of the garden and the field the same conditions of soil are desirable, although too difficult to regulate so perfectly. We can, however, by our processes and their proper timing, approximate sufficiently towards this condition to secure a gain.

We have thus far presented our illustrative facts, and the thinking whereby we have connected them in a measure with what we consider reasoned truths, adapted to practice and verification. We have, however, dealt with what may be called the mechanical consideration; but we would not have it inferred that this covers the whole field, for the chemical consideration also is of some large importance. Professor Johnson,* in 1871, said that a German investigator found that when a small amount of plaster, common salt, sulphate of soda or nitrate of soda, was incorporated with the soil, the quantity of water evaporated by the plant was reduced, in some cases, more than fifty per cent; and when a free alkali, like potash, was added, the quantity was also very strikingly diminished. In 1850, Sir J. B. Lawes'† trials showed a striking difference in the amount evaporated by certain plants on mineral manure, mineral and ammoniacal manure, and on unmanured soil, as follows: —

KIND OF PLANT.	TOTAL WATER GIVEN OFF BY		
	Unmanured Plants.	Plants on Mineral Manure.	Plants on Mineral and Ammoniacal Manure.
	Grains.	Grains.	Grains.
Wheat, 3 plants, ...	113,527	98,006	55,996
Barley, 3 plants, ...	120,025	128,354	85,124
Clover, 1 plant, ...	55,093	53,723	13,671

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* Ag. of Conn., 1871, p. 240.

† Hort. Trans., 1850, 45.

These figures correspond with the German results as stated by Professor Johnson. But Sir J. B. Lawes,* at a later date, shows certain modifications produced by fertilizer upon the water relation of the soil. On the plots where nitrate of soda was employed continuously year after year, the soil apparently retained very much more moisture, and presented other interesting physical characteristics, differing from those obtained on adjoining land. In some experiments by Professor Roberts,† at Cornell University, a mixture of salt and plaster was added to some soil in pots on July 11, and on August 16 the moisture in the soil was determined in the laboratory, with the result of finding increased water content in the soils to which salt and plaster had been applied. Other illustrative facts might be noted, and I think the observant person can readily adduce instances when salt or plaster or sulphate of soda or fertilizer has appeared to act beneficially as regards influencing the moisture in the land, always remembering that, unless the season be exceptionally dry, such observations can scarcely be successfully made. It is sufficient for my purpose here to simply call attention to this point.

I will but refer to the property that clay has of swelling when wet, and shrinking as it dries, by which it often so clogs the pores as to obstruct the capillary passage of water. The application of lime, or salt, or alum to water which will not deposit its sediment (settle), causes the clay to shrink at once and fall to the bottom; and it is believed that the application of these or other saline materials to clay soil often improves the drainage and capillary powers, by causing the clay to so shrink as to open the pores of the soil, when clogged, to the passage of capillary water. Professor Hilgard of California has well treated this subject under the title of flocculation.

We have now thought and talked science, a little discursively perhaps, as is becoming to the audience. We will now talk practice; and, in line with our preceding remarks, taking for our illustrative crop the corn plant, will put into plain form the information how we should grow, or attempt

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* Jour. R. A. S., 1871, p. 104; 1873, p. 370.

† Proc. of the Soc. for the Prom. of Agr. Science, 1888, p. 60.

to grow, a crop, the maximum for the fertility present, and offer certain explanations as we proceed.

First, we desire well-drained land; the reason wherefor is that stagnant water is injurious to growth, and so also is overmuch water. Then undrained land (and this is very important to consider), especially if clayey, is apt to become puddled, as it were, and hence to dry excessively during the droughty season, as we have before stated. What the crop requires in soil, for its best development during the growing season, if I may make a distinction, is moisture, not water. Drainage keeps the water table from rising above the drains, and thus preserves the soil above the drains from all but percolating water of rainfall and capillary water supply.

Commencing with suitable soil, we would manure or fertilize broadcast, and plough shallow, for reasons which I have given in a previous lecture, to be found in the twenty-eighth annual report of the secretary of the Massachusetts Board of Agriculture in 1881. The land should then be thoroughly harrowed, for the purpose not only of leveling and smoothing, but also in order to *consolidate the surface soil and bring the particles of earth into closer contact* (as the florist does in his pots by pressure), fill up the cracks and prepare for the next implement, which is the roller. This should be used thoroughly, *in order by its pressure to restore the capillary contacts* with the undisturbed soil below,* so as to secure the access of capillary water. These operations to be performed while the land is in a sufficiently dry condition not to puddle or cake.

Now plant your seed (under average conditions the earlier planted crop yields the best), the distances and quantities as enjoined by local experience; but in covering the seed be sure to either step on or otherwise compress the soil about the seed, in order to secure close contact of the seed and soil. This not only aids to secure moisture for germination, but obliterates cavities in which mould can grow, to the destruction of the seed, and in early planted seed which is long in germinating, mould is usually very destructive. I will not speak here of seed selection and variety, or of the impor-

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* A heavy rain after harrowing and before planting, or just after planting, is often of great service, doing the work of the roller, but more efficiently.

tance of good seed, as this matter has been sufficiently treated of by me elsewhere, and offers sufficient material for extended remarks.

At the season of planting there is always sufficient moisture, so the field can now be safely left, but in a condition, it is true, for great evaporative loss of water. As soon, however, as the plant attains the proper size, and the earlier the better, put in the cultivator and thoroughly stir the soil, so as to break the capillary connections with the surface and prevent by the mulch of loose soil the access of water to the surface to be evaporated, and thus economize the water in the lower soil for future needs. Remember, a proper cultivation is irrigation! The succeeding cultivations can properly follow no definite intervals. The object is to conserve moisture, and hence *whenever through rain or otherwise the surface hardens and establishes surface connections to the capillary pores*, *put in the cultivator* and re-establish the mulch. Get rid of the idea that the object of cultivation is directly to destroy the weeds and thus prevent their robbing the soil of the nitrogen, phosphoric acid and potash that they appropriate. The object in destroying the weeds is to prevent their robbing the soil of water, for this fertilizer robbery that has been so magnified by some lecturers can readily be offset by a few handfuls of extra fertilizer, but to replace the water thus lost would require barrels and team labor. After the ears of corn have commenced to glaze, even have just passed out of the milk, the requirements are dryness for the proper maturing of the crop, hence, the last cultivation can theoretically cease at the period when practical experience says stop, on account of the obstruction caused by the large growth of the plant. At and after this period weeds may be of no disadvantage, but help dry the soil, and after the last of August, in this climate, with early planted corn, it is probable that the corn plant matures its grain from the material already stored within its tissues. Late weeds also act in part as a green crop to pick up nitrogen and conserve it against the percolating rains of autumn and winter, and this green crop, when ploughed under the following spring, is ready through decay to release this saved and stored nitrogen to the succeeding crop. In the Middle South and South the value of late weeds is such that in localities the sowing of weed seed at the last cultivation could be wisely recommended did not nature usually usurp the privilege from her abundant stores.

Following the plan of my essay, I may add parenthetically, as it were, that in raising the maximum crop which I have figured on, I would by preference use at least some artificial fertilizer, for the reasons offered, by which we may believe that chemicals have an influence upon the economizing of the water content of the soil, but, for the same reasons I have given before, I shall not dwell further upon this branch of my subject.

After this presentation I may rightfully appeal to the thoughtful intelligence of my audience to corroborate or deny the practical conclusions from their oft-repeated experience. Let the question be honestly asked, are these things true, are they properly noted, are the arguments valid, are they in accord with an educated, practical common sense? If the answer is yes, then agree with me that my title is a proper one, that *brains* with *water*, and, as we all know, *nitrogen*, *phosphoric acid* and *potash* are the paramount fertilizers for the farmer; but the greatest of these is brains.